Designation: D7195 – 16a

Standard Guide for Setting Object Color Specifications[1]

This standard is issued under the fixed designation D7195; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide leads the user through a process for establishing color specifications, including the target color and allowable tolerances. It refers to the appropriate ASTM standards that more thoroughly describe each step of the process beginning with expectations, encompassing caveats within the process and finally concluding with reporting.

1.2 This guide does not suggest numerical values for tolerances. These values must be agreed upon by the parties involved.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D523 Test Method for Specular Gloss
D1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials
D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
D3134 Practice for Establishing Color and Gloss Tolerances
D3964 Practice for Selection of Coating Specimens for Appearance Measurements
D4086 Practice for Visual Evaluation of Metamerism
D4449 Test Method for Visual Evaluation of Gloss Differences Between Surfaces of Similar Appearance
D5531 Guide for Preparation, Maintenance, and Distribution of Physical Product Standards for Color and Geometric Appearance of Coatings
E179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials
E284 Terminology of Appearance
E308 Practice for Computing the Colors of Objects by Using the CIE System
E805 Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials
E1164 Practice for Obtaining Spectrometric Data for Object-Color Evaluation
E1345 Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements
E1347 Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry
E1499 Guide for Selection, Evaluation, and Training of Observers
E1708 Practice for Electronic Interchange of Color and Appearance Data
E1808 Guide for Designing and Conducting Visual Experiments
E2214 Practice for Specifying and Verifying the Performance of Color-Measuring Instruments
E2867 Practice for Estimating Uncertainty of Test Results Derived from Spectrophotometry

2.2 *CIE Publications:*

CIE Publication 015 Colorimetry[3]

3. Terminology

3.1 *Definitions*—For definitions of terms related to this guide see Terminology E284.

4. Summary of Guide

4.1 This guide describes the process for establishing color specifications for a material, including the decision as to whether this specification will be based on visual or instrumental methods.

4.2 General considerations of appearance, evaluation of observers, and measurement techniques are included.

4.3 It begins the process of setting a tolerance by first selecting a standard or target color for the material, including the production, measurement, and storage of that target.

[1] This guide is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.04 on Color and Appearance Analysis.

Current edition approved Aug. 1, 2016. Published September 2016. Originally approved in 2006. Last previous edition approved in 2016 as D7195 – 16. DOI: 10.1520/D7195-16A.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from CIE (International Commission on Illumination), http://www.cie.co.at or http://www.techstreet.com.

4.4 It next identifies methods to establish acceptable color tolerances.

4.5 Finally, it discusses reporting techniques.

5. Significance and Use

5.1 The rejection of materials due to color is a common and expensive occurrence, and it is useful for a customer and producer to set color specifications with an associated tolerance before the transaction. This guide discusses the concept and details the ASTM standards to be used in the process.

6. Introduction

6.1 A common reason stated for rejection of goods or materials is that the product color does not meet expectations. The best way to avoid the problem of returned goods or materials because of color is to establish color specifications with associated tolerances. Then the producer can be confident that if they supply material that falls within the specification, the customer will accept the product.

6.2 To supply product within specification consistently requires production that is under statistical process control, and a program of color measurement and evaluation.

6.3 This guide will lead the user through the decision-making process and point to the appropriate ASTM standards that are pertinent to each step. It will include the discussion points on which the two parties must agree and will provide caveats for various options selected.

7. General Discussions

7.1 In setting up the specification, one must first decide whether there will be a visual or instrumental evaluation of the color. Observers have different color perception skills. A highly trained colorist can see very minute color differences whereas the more casual observer or color-anomalous observer would not normally detect very small differences. Additionally, the visual abilities or perception levels of observers, may vary between persons and over time within an individual. Thus if the color of the material will be evaluated visually, we must ensure consistent conditions for the evaluation. Guide E1499 provides detailed information about the selection of observers. Guide E1808 provides guidance on how to conduct critical visual observations.

7.2 Numerous advances have occurred in both the accuracy and repeatability of color measurement instruments. However, there may still be considerable differences between instruments of different make, type, and geometry. Advances have also occurred in the equations and software programs for evaluating color and color quality control. It is not uncommon for the specification to be set numerically and evaluated by instrumental measurement, but then the question "what should my tolerance be?" must be resolved.

7.3 A number of color difference calculations are widely used throughout industry. See Practice D2244 for more details on color difference and color tolerance equations. Which color-difference metric will be used should be agreed upon by the two parties involved. For years, color tolerances were set up as rectangular tolerancing. In some industries the phrase "box tolerancing" is the accepted terminology. However, elliptical tolerancing is preferred.

7.4 In most cases, the limits of acceptability will be greater than a just perceptible difference, but in some cases, the tolerance may be less than a perceptible difference. If it is less than a perceptible difference, then instrumental methods should be used. Both the producer and the customer should refer to Practice E2214.

7.5 While the goal is to have an agreed color specification with an acceptable tolerance for both the producer and the customer, each party must carefully consider their position. The producer should be assured that they are able to control the color in production to the level specified without excessive waste and undue loss. The customer should be assured that the tolerance is such that the color of the goods will be acceptable.

7.6 Color is one aspect of the appearance of a material. Other appearance parameters include, but are not limited to, gloss, haze, and texture. In order to compare the color of a test material to a target material, either visually or instrumentally, all aspects of appearance should be the same, or as similar as possible. Test Method D4449 covers the visual evaluation of gloss difference, while Test Method D523 covers instrumental gloss measurement.

7.7 It is important to use established and consistent viewing conditions. These include the illumination, the positioning of the standard and specimen, and the receptor system, whether human or instrumental. If one is trying to have instrumental readings that correlate with the visual appearance of a material, one needs to establish consistency between the visual situation and the instrumental set up. Guide E179 discusses the terminology and instrumentation for evaluating appearance characteristics. Some of the considerations when choosing the geometry of evaluation are:

7.7.1 What are one's internal needs such as formulation, quality control, auditing, trouble shooting?

7.7.2 What are one's customer's specifications and needs?

7.7.3 Does one want the numbers to match visual evaluation?

7.7.4 If the gloss or surface texture of the standard and specimen are different, does one want specimen's gloss or grain levels to produce the same colorimetric values as the standard when measured?

7.7.5 Does one want to deal with a small or large process window?

7.8 It is important to have the producer and the customer agree on the target color and the criteria for acceptance. For many users the final criterion is visual acceptance, that is, visual color is the final deciding factor. However, some users have demonstrated that more consistent product quality is obtained instrumentally, avoiding the "final visual inspection." Once the color is agreed upon, then one should decide whether to use visual or objective standards and tolerances.

7.8.1 Some of the advantages of using a digital standard are:

7.8.1.1 Both supplier and customer have the same absolute numbers to judge against, the same starting point,

7.8.1.2 Reduced costs of making and maintaining master standards,

7.8.1.3 Easy to communicate an absolute number electronically, and

7.8.1.4 Faster; and fewer subjective calls.

7.8.2 Some of the disadvantages of using a digital standard are:

7.8.2.1 For best consistency, both supplier and customer must have the same instrument,

7.8.2.2 There is no physical standard available to use for a visual comparison,

7.8.2.3 The risk increases if different materials, technologies or different suppliers are used, and

7.8.2.4 There is less opportunity to ship acceptable-color product that matches but have numbers on the borderline or slightly greater than the numerical tolerance.

7.9 Maintaining master and working physical standards is discussed in detail in Guide D5531. However, some important aspects are repeated here.

7.9.1 Store master standards in a suitable protective material, under appropriate temperature and humidity conditions for the material to keep it in optimal condition (in the dark, away from heat sources, chemical fumes, direct sun-rays, etc.) and only remove when necessary to verify new working standards.

7.9.2 Maintain multiple working standards, with only one in circulation at a given time.

7.9.3 Handle master standards with lint-free gloves.

7.9.4 Record dates on all master and working standards when they are approved and by whom.

7.9.5 Frequently inspect working standards for scratches, changes in gloss or color.

7.9.6 Match to an approved (working master) part and routinely check the color difference between the master and the working master to ensure that the working standard has not changed.

NOTE 1—Once the working master has been established, it is desirable to use this rather than going back to the master because reference to the master can open the door for instrumental measurements and visual evaluations to be different.

7.10 All measured values have an uncertainty associated with the measurement. Estimate the uncertainty of test results using Practice E2867. To reduce the confidence limits associated with color or color-difference measurements statistical analysis of the results of multiple measurements on a single specimen or the measurement of multiple specimens can be used. This procedure is described in Practice E1345.

7.11 It is best if the standard and the trial material can be measured at the same time, on the same equipment by the same operator. Single operator precision is the best way to estimate production, test and raw material effects.

8. Procedure for Setting a Tolerance

8.1 Section 8 gives the steps for setting a tolerance. Table 1 summarized the ASTM Standards referenced for each of these steps.

TABLE 1 Summary of ASTM Standard Used

Color Specification Objective	ASTM Standard Reference
1. Physical Standard Measurement	D3964 – Practice for Selection of Coating Specimens for Appearance Measurements
	D5531 – Guide for Preparation, Maintenance, and Distribution of Physical Product Standards for Color and Geometric Appearance of Coatings
Test for Metamerism	D4086 – Practice for Visual Evaluation of Metamerism
2. Establishing a tolerance:	
Using historical samples	D1729 – Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials
Using experiments	E1808 – Guide for Designing and Conducting Visual Experiments
Measure specimens	E1164 – Practice for Obtaining Spectrometric Data for Object-Color Evaluation
	E1347 – Test Method for Color and Color-Difference Measurement by Tristimulus (Filter) Colorimetry
	E308 – Practice for Computing the Colors of Objects by Using the CIE System
Establishing tolerance	D3134 – Practice for Establishing Color and Gloss Tolerances
3. Produce Color Evaluation Report	E805 – Practice of Identification of Instrumental Methods of Color and Color-Difference Measurement of Materials
	E1708 – Practice for Electronic Interchange of Color and Appearance Data

8.2 The first step is to establish a physical (master) standard that represents the required color and to assure that all the (working) standards used in the control program match that color within a very small tolerance. See Practice D3964. Additionally, a program should be established to monitor the color quality of those working standards. See Guide D5531. Sample preparation is a very important issue. The surface characteristics and texture are important considerations and should be consistent.

NOTE 2—For coatings one might spray (using a specific procedure) or draw down the specimens. For other materials use techniques appropriate for those materials.

8.2.1 Ideally all the standards should be of the same material and texture as the product to be supplied, using the same pigments and dyes as used in the original formulation.

8.2.2 On occasion the target color cannot be used as the standard because it is not the same material or not made from the formulation that will be used in production. In this case, a standard should be produced from the material to be supplied. The producer and the customer should agree in writing that this specimen is an acceptable production standard. Metamerism between the target color and the standard should be minimized. The metamerism should be evaluated either instrumentally or visually. Practice D4086 describes the techniques for doing this visually. Comparison of the color difference between the target and standard calculated under different illuminants provides an instrumental measure of metamerism.

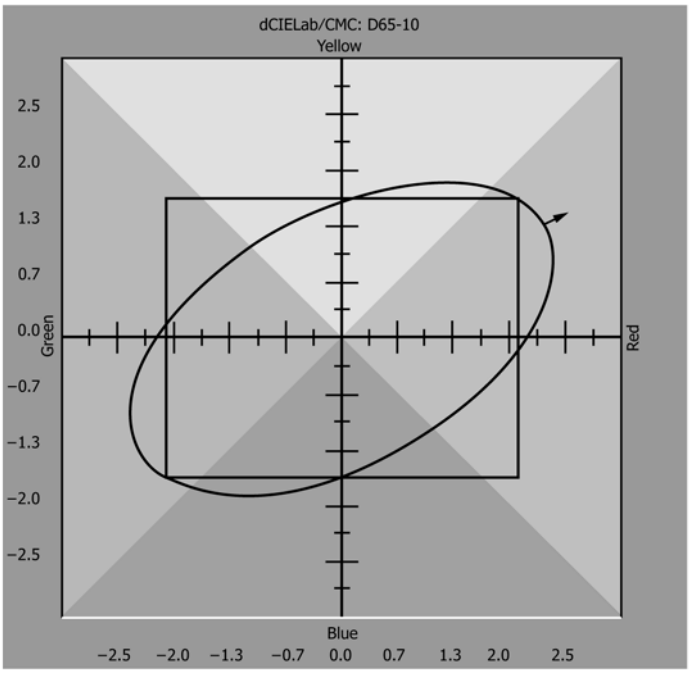

FIG. 1 Elliptical vs Rectangular or Box Tolerancing

8.3 The most accurate way to establish tolerances is to have a wide range of samples that have been visually evaluated as acceptable or unacceptable when compared to the standard. These can be historical samples taken from earlier production runs, or they can be samples produced specifically to develop tolerances. If you are using historical samples, see Practice D1729. If you are producing samples specifically to develop the tolerance, then follow Guide E1808.

8.3.1 These samples are then measured instrumentally, and the results are plotted in Lab space. See Practice E1164 or Test Method E1347. These two standards discuss the two basic types of measurements, spectrophotometry and filter colorimetry, respectively. Practice E308 discusses the procedure for converting from the measured values of spectral reflectance factor to the CIE X, Y, Z tristimulus values and the transformation of the tristimulus values into the CIE colorimetric values of L*, a*, b* and L*, C*, h.

8.3.2 An acceptability ellipse is then produced that encompasses the acceptable samples. See Practice D3134 and the reference by Berns.[4]

NOTE 3—A rectangular tolerance enclosed within the ellipsoid will exclude acceptable samples, and a rectangular tolerance enclosing the ellipsoid will include unacceptable samples. See Fig. 1.

8.4 When a large data base of acceptable samples is not available, it might be necessary to set the initial or preliminary tolerance using values calculated around the centroid of the standard. This initial tolerance should be validated as sample observations become available.

8.5 Generally, tolerances are presented in the LCh space, which is calculable from CIELAB space. The CIEDE2000 equation is the recommended color-difference expression that is based on the coordinates of CIELAB space that shows improved correlation of visual ratings and instrumental ratings of color differences.

8.5.1 Some people find it easier to discuss the position of a specimen in color space using the terms of lighter or darker, redder or greener, and yellower or bluer rather than in terms of hue angle and chroma as in an LCh specification. This is especially true and recommended in cases where the color center is close to neutral. The CIEDE2000 tolerancing is developed in LCh space. Therefore, it is possible convert to the data back to CIELAB space and maintain local spatial uniformity.

9. Report

9.1 When instrumental techniques are used for the final acceptance of the material before shipment, the color evaluation report should follow Practice E805.

9.2 Color evaluation data may be exchanged electronically between the producer and user. If this is to be done, it is useful to follow Practice E1708.

10. Keywords

10.1 box tolerance; color difference; color specification; color tolerancing; elliptical tolerance; instrumental measurement; rectangular tolerable; rectangular tolerance; tolerance; visual evaluation of color

[4] Berns, Roy S., "Deriving Instrumental Tolerances from Pass-Fail and Colorimetric Data;" *Color Research and Application 21:*459-472 (1996).